

Raga Rupa : Computer Analysis and Sangita-Shastra

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Abstract

Sangitashastra, the traditional Indian science of music, contains several ideas which are keys for the study, classification and analysis of raga music. These ideas form the base here for an analysis model realized as a computer algorithm. We look at the schema of the *Sangita Ratnakara* for different note functions. Then data for *alap* sketches in ragas Bihag and Kalyan composed and notated by three eminent musicians is analyzed using the analysis schema, to study how the notes have been used by the different musicians to define the raga-form (*raga rupa*).

We then turn our attention to the *varna*-s, the S.R.'s categories of how notes are used *in seriatim*. Using these categories, the analysis creates for each data sample a 'list of allowed moves' for the raga as it is manifested by the piece. Using this 'list' we isolate and study the contextual use of minimally sized kernels of musico-linguistic meaning. Lastly, we discuss the question of a generative grammar à la Chomsky's idea of trees of possibility.

1. The Functional Use of Notes: Ideas of the Sanskrit Musicological Tradition

1.1 *Shastra Lakshana*-s: *Graha*, *Amsha*, *Nyasa*, *Alpatva*, *Bahutva*

In the discussion of the characteristics (*lakshana*-s) of the musical modes (*jati*-s), Sarangadeva (S.R.I.7.29-57b) uses the terms *graha*, *amsha*, *nyasa*, *alpatva*, *bahutva* to refer to the type of use and, in some cases, the relative amount of use each of the notes receives in the different modes. Some musicians¹ still prefer to discuss ragas in these terms. When they do, however, they generally retain the root

1. Notable among whom were Pt Omkarnath Thakur and Ustad A. Rahimuddin Khan in the last generation.

idea of the original term but the scope of its application is not always the same. Since there is no way to know what the actual music of earlier periods was, it is not surprising that musicological traditions like that of the Dagar family's, which come down as a practical *sampradaya*-s (tradition), often keep only the root idea of a particular term, applying it with a new scope adjusted to the contemporary musical context.

1.2 Modern Usages of These Terms

In the Sangita Ratnakara (S.R.7.31) *graha*, for example, means the note which begins a piece. In this study we apply it to refer to a note's tendency to begin phrases. So too, *nyasa* according to the S.R. (7.38-40) is the last note of the piece, but here we use it to refer to those notes on which one may 'sit', so it means the tendency for a note to be used as a place of tension release, generally at the conclusion of a phrase.

In a raga for a note to be *amsha* (the term *vadi* is used more today) means, among other things, that it is placed in a position of prominence, i.e. is often repeated, held, accented etc. According to the S.R. (7.32-33) the charm of a mode is made manifest by the *amsha*, which divides the mode into *anga*-s (tetrachords).

The term *bahutva* literally means 'muchness' and *alpatva* has the opposite meaning (cf S.R.7.49-51). I am indebted to Ustad Asad Ali Khan for the idea that *bahutva* means the note is sustained, not just repeated.

2. Data for the Analysis of Ragas Bihag and Kalyan

Below is an *alap* sketch in raga Bihag, composed in *dhrupad* style by Dilip Chandra Veda in 1979. The music is in a minimally ornamented style, and so is ideal for this study. It is presented below as an example of the kind of data used, in the form that was entered into the computer. Other materials in Bihag and Kalyan taken from D.C. Veda, V. R. Patwardhan (*Raga Vigyana*), and Omkarnath Thakur (*Sangitanjali*) have been also used for this study, but they are not given here. Note that in order to see the total comparative weight of *madhyama* (the fourth) as a tonal degree, the computer analysis does not treat the two *madhyama*-s (F and F#) of Bihag as separate since the rule of their use is consistent.

2.1 *Alap Sketch for Raga Bihag: (Dilip Chandra Vedi)*

Sthayi

1. s.....rns.....n.....dp.....; pn...s...g.....rs.....; srsn...
dp...m...gm.....g.....; gmpn.....dp...m...mg.....g.....;
pdmp...mgm...g.....rs.....
2. pn.....dp...m...g.....mpn....., sg...mpn....., s...mgpmdp...
g...mpn....., pnsrnsn.....rs.....; pnsrnsn....., pnsrnsn.....
rnsn....., g...rnsn....., pnsrnsn.....g.....; sg...m...g...
nsm...g....., pnsrnsn.....g.....rs....., s...s...s...s...
n...s...g.....
3. dp.....m...g...mpn....., g...mpn....., n...sgmpn....., p...
nsgmpn....., n n...dp...mgm.....g.....; s...mgpmdp...
dp....., dm...mp...mgm...g....., s...gmdp...mgm...g.....,
smgp...mg...m...g....., g...mp...m...g.....rs....., s...s...s...
s..., n...s...g.....;

Antara

4. n.....dp...m...g...mpn....., g.....mpn....., g...mpd...g...
mpn....., n...sgmpn....., pn...s...g....., n...s...gmpn.....
s.....; pnsrnsn.....dp....., mpnsrnsn.....dp....., g...
mpns...rs...rnsn.....dp..., g—mpn—s—g..., gg.....rs.....; srsn...
n.....dp....., g...mpn.....dp.....; dm.....mp...mg...
m...g.....; smgpmdp...mg...m...g....., s...p...mg...
m...g....., g...mp...m...g.....rs....., s...s...s...s...
n...s...g.....
5. g...mpnsg....., n...sgmpnsg.....rs.....; g...mpnsrnsn.....
dp....., pnsrnsn.....dp....., nsrnsn.....dp....., n...
sgmpn.....dp.....; dm...mp...mg...m...g.....,
sgmdp...m...g...m...g....., smgpd...gm...g....., p...
mg...m...g.....rs..., s...s...s...s..., nsg.....

3. Statistical Summaries of Note Use in Key Contexts for Kalyan and Bihag

The algorithm which does the analysis has several parts. One part looks at every character in the melodic string and decides if it is a note or not. If it is, it keeps track of how many times the note has occurred and checks to see if it starts or ends a phrase. If so, that is counted. Then it looks to see whether the note fell on a rhythmically strong beat (was preceded by a "/" in the data). This column is empty for *alap*. If the datum is the symbol indicating that a previous datum was a note which is still being held, that fact is also noted.

The tables below summarize how notes were used in the contexts ('began phrase', 'ended phrase', 'was held', 'note's total density') in the *alap* data. The density of distribution graph displays the information of the latter column.

TABLE 3.1: FUNCTIONAL NOTE USE IN BIHAG SKETCH BY D.C. VEDI

<i>Various note functions</i>					<i>Total note use</i>
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	28.8	24.4	14.5	17.5%	Sa: xxxxxxxxxxxx
Re:	—	—	—	2.7%	Re: xx
Ga:	27.3	36.4	35.1	27.6%	Ga: xxxxxxxxxxxxxxxxxxxx
Ma:	1.5	—	11.7	14.1%	Ma: xxxxxxxxxxxx
Pa:	24.2	16.7	14.5	14.9%	Pa: xxxxxxxxxxxx
Dha:	4.5	—	0.5	2.9%	Dha: xx
Ni:	13.6	22.7	23.7	20.2%	Ni: xxxxxxxxxxxx

(Figures are in %.)

TABLE 3.2: FUNCTIONAL NOTE USE IN BIHAG SKETCH BY V.R. PATWARDHAN (R.V.2.176)

<i>Various note functions</i>					<i>Total note use</i>
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	39.1	43.5	19.6	18.6%	Sa: xxxxxxxxxxxx
Re:	17.4	—	—	3.7%	Re: xx
Ga:	21.7	52.2	34.6	29.3%	Ga: xxxxxxxxxxxxxxxxxxxx
Ma:	—	—	21.5	21.8%	Ma: xxxxxxxxxxxxxxxx
Pa:	8.7	—	11.2	10.7%	Pa: xxxxxxxx
Dha:	—	—	—	1.7%	Dha: x
Ni:	13.0	4.3	13.1	14.1%	Ni: xxxxxxxxxxxx

TABLE 3.3: FUNCTIONAL NOTE USE IN BIHAG SKETCH BY PT OMKARNATH (S.A.2.2)

<i>Various note functions</i>					<i>Total note use</i>
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	23.5	39.2	23.1	17.8%	Sa: xxxxxxxxxxxx
Re:	9.8	—	—	3.0%	Re: xx
Ga:	11.8	29.4	27.1	23.0%	Ga: xxxxxxxxxxxxxxxx
Ma:	9.8	—	41.0	20.9%	Ma: xxxxxxxxxxxxxxxx
Pa:	19.6	21.6	22.1	17.9%	Pa: xxxxxxxxxxxx
Dha:	7.8	—	—	3.4%	Dha: xx
Ni:	17.6	9.8	13.7	14.0%	Ni: xxxxxxxxxxxx

TABLE 3.4: FUNCTIONAL NOTE USE IN KALYAN SKETCH BY D.C. VEDI

Various note functions					Total note use
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	10.0	25.7	15.1	13.4%	Sa: xxxxxxxxxxxx
Re:	14.3	—	5.9	10.7%	Re: xxxxxxxx
Ga:	12.9	34.3	30.6	23.3%	Ga: xxxxxxxxxxxxxxxxxxxx
Ma:	22.9	1.4	9.2	12.9%	Ma: xxxxxxxxxxxx
Pa:	5.7	22.9	18.3	12.7%	Pa: xxxxxxxxxxxx
Dha:	12.9	—	2.2	8.5%	Dha: xxxxxx
Ni:	21.4	15.7	18.7	18.6%	Ni: xxxxxxxxxxxxxxxxxxxx

TABLE 3.5: FUNCTIONAL NOTE USE IN KALYAN SKETCH BY V.R. PATWARDHAN (R.V.2. 147)

Various note functions					Total note use
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	12.2	27.5	20.1	13.8%	Sa: xxxxxxxxxxxx
Re:	0.0	5.0	8.9	14.1%	Re: xxxxxxxxxxxx
Ga:	26.8	35.0	28.1	22.6%	Ga: xxxxxxxxxxxxxxxxxxxx
Ma:	12.2	—	12.1	13.8%	Ma: xxxxxxxxxxxx
Pa:	9.8	12.5	13.4	10.8%	Pa: xxxxxxxx
Dha:	12.2	—	2.7	7.9%	Dha: xxxxxx
Ni:	26.8	20.0	14.7	16.9%	Ni: xxxxxxxxxxxxxxxxxxxx

TABLE 3.6: FUNCTIONAL NOTE USE IN KALYAN SKETCH BY PT OMKARNATH THAKUR (S.A. 2.124)

Various note functions					Total note use
Note	Begin phrase	End phrase	Held	Total density	Density of distribution
Sa:	10.7	27.4	12.7	9.4%	Sa: xxxxxx
Re:	13.1	22.6	22.2	20.9%	Re: xxxxxxxxxxxxxxxxxxxx
Ga:	6.0	23.8	22.5	19.3%	Ga: xxxxxxxxxxxxxxxxxxxx
Ma:	17.9	—	11.0	14.2%	Ma: xxxxxxxxxxxx
Pa:	1.2	10.7	8.8	7.3%	Pa: xxxxxx
Dha:	14.3	8.3	8.0	11.3%	Dha: xxxxxxxx
Ni:	36.9	7.1	14.9	17.7%	Ni: xxxxxxxxxxxxxxxxxxxx

4. Comparisons of Differences in the Functional Use of Notes

Comparing Bihag with Kalyan, the density distribution of note use in the two ragas shows a considerable difference as expected. When different musicians versions of the same raga are compared, however, there are striking similarities and differences.

4.1 Comparison: Bihag

All three sketches of Bihag agree in giving maximum exposure to *gandhara* (E). This note is considered to be the *vadi* note (i.e. *amsha*) of the raga by all three musicians. *Nishada* (B), at the distance of a fifth in the upper tetrachord is likewise considered to be its *samvadi*. In the data there is agreement that *nishada* (B) is strong, but both Patwardhan and Thakur have given it less importance to it than they have to *madhyama* (the fourth). Vedi and Thakur agree that *pancama* (G) should be strong. Patwardhan disagrees. One suspects that for Patwardhan *madhyama* (the fourth) resolves much more commonly to *gandhara* (E) than to *pancama* (G). All three agree that *rishabha* (D) and *dhaivata* (A) are weak *alpa* in the raga.

4.2 Comparison: Kalyan

In Kalyan all three musicians have agreed about the importance of *gandhara* (E), the note said to be the raga's *amsha* (although somewhere Thakur disputes this, arguing in favour of *rishabha* (D) — a fact which is evident too in the analysis of his example). Its *samvadi* is considered to be *nishada* (B) in the upper tetrachord, a strong note in all the examples. Vedi and Patwardhan show close general agreement with each other except for the use of *pancama* (G) which Patwardhan uses less. Thakur, on the other hand, makes considerably less use of *sadja* (C) and *pancama* (G) than the others, and he also puts a good deal more emphasis on *rishabha* (D). Since *rishabha* (D) and *dhaivata* (A) are in some sense parallel, it is not surprising that he gives *dhaivata* (A) more emphasis, too.

5. Analysis Summaries by *Laksana*

Information for several of the *laksanas* mentioned in 1.1 above can be extracted from the entries in the Tables 3.1 to 3.6. The information available in columns 'begin phrase' and 'end phrase' indicates the relative importance of the notes as *graha* and *nyasa*

respectively. The entries in the *amsha* tables below order by rank the percentages of the sum of notes used, held, and accented. (Since no accent is indicated for *alap*, the figures in the *amsha* and the 'Total' columns are identical, but in compositions or in *tana-s* accent can be significant in deciding whether a note should be considered '*amsha*'.) *Bahutva* and its opposite *alpatva* are determined by how much the note was held.

The tables below rank notes according to the occurrence of their use for the particular *laksana*. The computer calculates the standard deviation of the percentage figures in the columns. In the tables below the exclamation point '!' flags notes whose percentage occurrences in the capacity of the *laksana* are higher than mean plus half the standard deviation. These notes are the prime candidates to be assigned the quality conveyed by the technical term if the model is correct.

TABLE 5.1: RAGA BIHAG

<i>Graha Bihag (Vedi)</i>		<i>Graha Bihag (Pṭwrdhn)</i>		<i>Graha Bihag (Thakur)</i>	
Sa: xxxxxxxxxxxx	29%!	Sa: xxxxxxxx xxxxxxx	39%!	Sa: xxxxxxxxxxx	24%!
Re:	0%	Re: xxxxxx	17%	Re: xxxx	10%
Ga: xxxxxxxxxxxx	27%!	Ga: xxxxxxxx	22%!	Ga: xxxxx	12%
Ma: x	2%	Ma:	—	Ma: xxxx	10%
Pa: xxxxxxxxxxxx	24%	Pa: xxx	9%	Pa: xxxxxxxx	20%!
Dha: xx	4%	Dha:	—	Dha: xxx	8%
Ni: xxxxx	14%	Ni: xxxxx	13%	Ni: xxxxxxxx	18%
5.1.1		5.1.2		5.1.3	
<i>Nyasa Bihag (Vedi)</i>		<i>Nyasa Bihag (Pṭwrdhn)</i>		<i>Nyasa Bihag (Thakur)</i>	
Sa: xxxxxxxx	24%!	Sa: xxxxxx xxxxxx	44%!	Sa: xxxxxx xxxxxx	39%!
Re:	—	Re:	—	Re:	—
Ga: xxxxxx	—	Ga: xxxxxx	—	Ga: xxxxxxxx	29%
Ma: xxxxxx	36%!	Ma: xxxxxxxx	52%!	Ma:	—
Pa: xxxxx	17%	Pa:	—	Pa: xxxxxxxx	22%
Dha:	—	Dha:	—	Dha:	—
Ni: xxxxxxxx	23%!	Ni: x	4%	Ni: xxx	10%
5.1.4		5.1.5		5.1.6	

<i>Amsha Bihag (Vedi)</i>	<i>Amsha Bihag (Ptwrhdn)</i>	<i>Amsha Bihag (Thakur)</i>
Sa: xxxxxxxx 18%! Re: xx 3% Ga: xxxxxxxx xxxxxx 28%! Ma: xxxxxx 14% Pa: xxxxxxxx 15%! Dha: xx 3% Ni: xxxxxxxxxxxx 20%	Sa: xxxxxxxx 19% Re: xx 4% Ga: xxxxxxxx xxxxxx 29%! Ma: xxxxxxxxxxxx 22%! Pa: xxxxxx 11% Dha: x 2% Ni: xxxxxxxx 14%	Sa: xxxxxxxx 18% Re: x 3% Ga: xxxxxxxx xxxxxx 23%! Ma: xxxxxxxxxxxx 21%! Pa: xxxxxxxxxxxx 18% Dha: x 3% Ni: xxxxxxxx 14%
5.1.7	5.1.8	5.1.9
<i>Bahutva Bihag (Vedi)</i>	<i>Bahutva Bihag (Ptwrhdn)</i>	<i>Bahutva Bihag (Thakur)</i>
Sa: xxxxxx 14% Re: — Ga: xxxxxxxx xxxxxx 35%! Ma: xxxxxx 12% Pa: xxxxxx 14% Dha: — Ni: xxxxxxxxxxxx 24%	Sa: xxxxxxxx 20% Re: — Ga: xxxxxxxx xxxxxx 35%! Ma: xxxxxxxxxxxx 22%! Pa: xxxxxx 11% Dha: — Ni: xxxxxxxx 13%	Sa: xxxxxxxxxxxx 23%! Re: — Ga: xxxxxxxx xxxxxx 27%! Ma: xxxxxx 14% Pa: xxxxxxxxxxxx 22%! Dha: — Ni: xxxxxxxx 14%
5.1.10	5.1.11	5.1.12

5.2: Key Concepts and Questions

The above tables summarize how the features:

1. *graha*: (starting notes of phrases and subphrases),
2. *nyasa*: (notes on which phrases and subphrases end),
3. *amsha*: (prominant and key notes for raga's total effect),
4. *bahutva*: (notes which are sustained),

are used in raga Bihag according to *alap* sketches of three different musicians representing different schools (*gharana*-s). Since these *laksana*-s define raga key features, it is interesting to see what we can understand about the form (*rupa*) of the ragas as these musicians conceive it. On what features is there agreement by all? On what features do only some agree? Does any person's conception show facts which are unusual or unique to him? These are our questions.

6. Raga Bihag: Stylistic Different Perspectives Visible by Looking at the *Laksana*-s

6.1 *Graha*

All three agree on the importance of *sadja* (C) as the principle

starting note for phrases. Few phrases are started from *dhaivata* (A) and *madhyama* (the fourth). Vedi and Thakur start many phrases from *pancama* (G) as well as *sadja* (C) while Patwardhan does so less than half their amounts. Vedi and Thakur disagree, however, about the use of *gandhara* (E), Vedi starting phrases with it twice as often as Thakur. While both Vedi and Patwardhan agree about the relative importance of *gandhara* (E) and *nishada* (B), they disagree sharply about *rishabha* (D) and also *pancama* (G). Vedi's non-use of *rishabha* (D) as *graha* stands out as unusual.

6.2 Nyasa

All three agree about the importance of *sadja* (C) and *gandhara* (E) as notes of tension release in this raga, and further, that one must not come to a stop on *rishabha* (D), *madhyama* (the fourth), or *dhaivata* (A). Patwardhan, nevertheless, has given even more emphasis to *gandhara* (E). It is curious that he has never used *pancama* (G) as a stopping note, which is done quite commonly by the other two. Vedi makes the most use of *nishada* (B), and Thakur the most of *pancama* (G). The most balanced picture is Vedi's. Patwardhan has more or less indicated no notes to stop phrases on in the whole upper tetrachord. Thakur too, favors the lower tetrachord.

6.3 Amsha

All agree on the importance of *gandhara* (E) as *amsha*, and the non-importance of *dhaivata* (A). Vedi uses less *madhyama* (the fourth) than the others, for whom it qualifies as *amsha*. The structure of his balance on which notes to bring out is open because he has the three notes, *sadja* (C), *gandhara* (E), and *pancama* (G), as *amsha* rather than two closely situated together in mid-octave. Patwardhan uses the least *pancama* (G) while Vedi uses the most *nishada* (B).

6.4 Bahutva

All agree that *gandhara* (E) has *bahutva* and that *rishabha* (D) and *dhaivata* (A) are *alpatva* in Bihag. Vedi and Patwardhan have sustained *pancama* (G) about the same while Thakur has held it much more. Vedi holds *nishada* (B) the most and *madhyama* (the fourth) the least of the three. Patwardhan holds *madhyama* (the fourth) the most.

7. Raga Kalyan

TABLE 7.1: RAGA KALYAN: LAKSANA SUMMARIES

<i>Graha Kalyan (Vedi)</i>	<i>Graha Kalyan (Ptwardhn)</i>	<i>Graha Kalyan (Thakur)</i>
Sa: xxxx 10%	Sa: xxxxx 12%	Sa: xxxx 11%
Re: xxxxxx 14%	Re: —	Re: xxxxxx 13%
Ga: xxxxx 13%	Ga: xxxxxxxxxxxx 27%!	Ga: xx 6%
Ma: xxxxxxxx 23%!	Ma: xxxxx 12%	Ma: xxxxxxxx 18%
Pa: xx 6%	Pa: xxxxx 10%	Pa: — 1%
Dha: xxxxx 13%	Dha: xxxxx 12%	Dha: xxxxxxxx 14%
Ni: xxxxxxxx 21%!	Ni: xxxxxxxxxxxx 27%!	Ni: xxxxxxxx 37%! xxxxxxx
7.1.1	7.1.2	7.1.3
<i>Nyasa Kalyan (Vedi)</i>	<i>Nyasa Kalyan (Ptwardhn)</i>	<i>Nyasa Kalyan (Thakur)</i>
Sa: xxxxxxxxxxxx 26%!	Sa: xxxxxx 28%!	Sa: xxxxxx 27%!
Re: —	Re: xx 5%	Re: xxxxxxxxxxxx 23%!
Ga: xxxxxxxx 34%!	Ga: xxxxxxxx 35%!	Ga: xxxxxxxxxxxx 24%!
Ma: x 1%	Ma: —	Ma: —
Pa: xxxxxxxxxxxx 23%!	Pa: xxxxx 12%	Pa: xxxxx 11%
Dha: —	Dha: —	Dha: xxx 8%
Ni: xxxxxx 16%	Ni: xxxxxxxxxxxx 20%	Ni: xxx 7%
7.1.4	7.1.5	7.1.6
<i>Amsha Kalyan (Vedi)</i>	<i>Amsha Kalyan (Ptwardhn)</i>	<i>Amsha Kalyan (Thakur)</i>
Sa: xxxxxx 13%	Sa: xxxxxx 14%	Sa: xxxx 9%
Re: xxxxx 11%	Re: xxxxxx 14%	Re: xxxxxxxxxxxx 21%!
Ga: xxxxxxxx 34%!	Ga: xxxxx 23%!	Ga: xxxxxxxxxxxx 19%!
Ma: xxxxxx 13%	Ma: xxxxxxxx 14%	Ma: xxxxxxxx 14%
Pa: xxxxxx 13%	Pa: xxxxx 11%	Pa: xxx 7%
Dha: xxxx 8%	Dha: xxxxx 8%	Dha: xxxxx 11%
Ni: xxxxxxxx 19%!	Ni: xxxxxxxx 17%!	Ni: xxxxxxxxxxxx 18%!
7.1.7	7.1.8	7.1.9

<i>Bahutva Kalyan (Vedi)</i>		<i>Bahutva Kalyan (Ptwardhn)</i>		<i>Bahutva Kalyan (Thakur)</i>	
Sa: xxxxxxx	15%	Sa: xxxxx xxxxx	20%! 9%	Sa: xxxxxx	13%
Re: xxx	6%	Re: xxxxx	9%	Re: xxxxxxxxxxx	22%! 22%
Ga: xxxxxxx		Ga: xxxxxxx		Ga: xxxxxxxxxxx	
xxxxxx	31%!	xxxxxx	28%!		
Ma: xxx	9%	Ma: xxxxx	12%	Ma: xxxxx	11%
Pa: xxxxxxx	18%	Pa: xxxxxxx	13%	Pa: xxx	9%
Dha: x	2%	Dha: x	3%	Dha: xxx	8%
Ni: xxxxxxx	19%	Ni: xxxxxxx	15%	Ni: xxxxxxx	15%
7.1.10		7.1.11		7.1.12	

7.2 Raga Kalyana: Stylistic Different Perspectives Visible by looking at the Laksana-s

7.3 Graha

All agree that *nishada* (B) is an important note for starting phrases. Vedi and Thakur also consider *madhyama* (the fourth) and *rishabha* (D) important too, while Patwardhan prefers to start phrases from *gandhara* (E). Also both give some importance to *rishabha* (D) which Patwardhan avoids. Patwardhan starts phrases from *pancama* (G) the most. All three make about the same use of *dhaivata* (A).

7.4 Nyasa

All agree of the importance of *gandhara* (E) and *sadja* (C) for ending phrases and all avoid to end them on *madhyama* (the fourth). Vedi and Patwardhan further avoid *dhaivata* (A) in this context as well as, to a lesser extent, *rishabha* (D). Thakur's treatment of *rishabha* (D) is unusual by comparison. He is ending 74% of his phrases in the lower tetrachord, on *sadja* (C), *rishabha* (D), and *gandhara* (E). Both Vedi and Patwardhan present a more balanced picture of *nyasa* than Thakur. Vedi makes a neat balance of importance of *sadja* (C) and *pancama* (G) while Patwardhan and Thakur use much less *pancama* (G) as *nyasa*.

7.5 Amsha

All agree that *gandhara* (E) and *nishada* (B) have this quality. Thakur, in addition, has given the same status to *rishabha* (D). The notes *sadja* (C) and *pancama* (G) are slightly used by Thakur, while

madhyama (the fourth) is used about equally by all. Given the importance Thakur assigns to *rishabha* (D) here, it is not surprising that he makes the maximum use of *dhaivata* (A) of the three. Vedi has used an unusual amount of *gandhara* (E). The Most balanced picture of the three is Thakur's.

7.6 *Bahutva*

All agree that *gandhara* (E) is to be prolonged. Patwardhan has also prolonged *sadja* (C) much while Thakur has done so with *rishabha* (D). Vedi assigns the most importance to *pancama*, then Patwardhan, and least is assigned by Thakur. Thakur has prolonged *dhaivata* (A) the most while Vedi has made the most use of *nishada* (B). The best balance seems to be in Vedi or Patwardhan.

8. Bihag and Kalyan: Summary of Characteristics

8.1 *Comparison of the two Ragas*

Bihag is evidently the more consonant of the two ragas which both share the same scale type (*gandhara murcchana* of *madhyamagrama* [Arnold: 1983, 1984]). It makes considerably more use of the consonant pair (S,P) than does Kalyan. Like Kalyan, Bihag makes much use of *gandhara* (E), both as an *apanyas* (like *nyasa* but terminating sub-sections-cf S.R. 7.41-47b) and *amsha*. The two qualities are in fact related. It is curious that neither Patwardhan nor Thakur really bring out clearly the relation between *gandhara* (E) and *nishada* (B) as Vedi has done.

Kalyan has the bolder tonality of the two ragas because of its prominent consonant pair (G,N) existing without the strong supporting (S,P) pair. Like Bihag the pair (R,D) is treated with less emphasis by Vedi and Patwardhan. Thakur, however, disagrees with this view of Kalyan, and gives this consonant pair more importance.

Vedi's Bihag and Kalyan both have the same notes *alpatva* and *bahutva*, and share common features of *nyasa*. They are very different in *graha* and *amsha*. Patwardhan's Bihag and Kalyan have the same notes for both *naysa* and *alpatva*. Each of the remaining note functions of the two ragas share one common note and differ on the other. Thakur's Bihag and Kalyan show the most difference.

The tables below summarize how each artist used each note function for each raga.

TABLE 8.1.1: BIHAG

Note-function	Vedi	Patwardhan	Thakur
<i>Graha</i>	S,G,P	S,G	S,P,N
<i>Nyasa</i>	S,G,N	S,G	S,G
<i>Amsha</i>	S,G,P	G,M	G,M
<i>Bahutva</i>	G	G,M	S,G,P
<i>Alpatva</i>	R,D	R,D	R,D

TABLE 8.1.2: KALYAN

Note-function	Vedi	Patwardhan	Thakur
<i>Graha</i>	M,N	G,N	N
<i>Nyasa</i>	S,G,P	S,G	S,R,G
<i>Amsha</i>	G,N	G,N	R,G,N
<i>Bahutva</i>	G	S,G	RG
<i>Alpatva</i>	R,D	R,D	D,P,M

9. Raga Grammar: Two-note Connections

Having established a procedure for evaluating the different features a raga's notes may exhibit, let us turn our attention to concepts which describe how they are used *in seriatim*. The aim is to arrive at a minimum set of concepts and technical terms necessary to allow us to analyze what were the actual moves used from one note to the next in the three Bihag and three Kalyan sketches.

9.1 Key Ideas from the Sanskrit Musicological Tradition

9.2 Aroha-avaroha

Sangita-shastra approaches the question of defining rules for the serial use of notes through the concepts of ascending (*aroha*) melodic movement (*tana*) and descending (*avaroha*) movement (S.R.4.9-26b). Similar use is made of this idea today. The structure of a raga is usually expressed in terms of what notes are to be omitted when ascending or descending. For example, if a raga omits *rishabha* (D)

and *dhaivata* (A) in ascent, but takes them in descent, its *aroha-avaroha* structure is S-G-M-P-N-S, S-N-D-P-M-G-R-S. Where such a situation obtains any stepwise motion which takes place must follow this pattern. Given the above structure, for example, the phrase N-S-G-M-P will be correct for the raga, but the phrase N-S-R-M-P will not be.

9.3 Kuta tana-s (Merukhand)

The idea of *aroha* and *avaroha* will guide us for stepwise motion. But what about the connections G—P or P—R? It is not clear whether they are allowed, so one additionally requires the concept of the *tana*, especially as Sharangadeva has elaborated it for *kuta tana-s* in the *Sangita Ratnakara* (S.R. 4.31c—35a ff.). The sets of *kuta tana-s*, which are popularly known as the system of *merukhand* are created by systematically permuting (*khandameru*) all the combinations of joining any given number (n) of notes (from 1 to 7) together without repeating any note. The resulting number of combinations is equal to the factorial of (n).

The strength of the *kuta tana-s* is its completeness; however, it defines a set of note combinations which is much too large to want to take it in its full. For our purposes, we look only at the set of two-note *sangati-s* (connections) found in the *khandamaru*. As this set fills up in analysis, it constitutes a list of allowed moves for the raga as presented in the sketch. Similarly, any piece so analyzed will provide a paradigm of simple grammatical rules of the raga, a grammar that is rudimentary since it only discriminates between 'legal' or 'illegal' moves. There are 42 two-note *kuta tanas* since there are 42 ways (given seven notes) to take one after another without repeating any one. We shall also count the 7 additional cases when the note repeats itself.

10. Sangati-lists for Bihag and Kalyan

The programme *Raganal* has been designed to scan the melody data, also to determine which two-note combinations have occurred, and in what percentages. Not only do we know, therefore, what moves were considered legal, according to the input data, but we also know relatively how much each move was used over the whole piece. Below in the tables are given the *sangati*-lists for the *alap* outlines in Bihag and Kalyan.

TABLE 10.2: TWO-NOTE AROHA-SANGATI-S: BIHAG

<i>Vedi</i>		<i>Paiwardhan</i>	<i>Thakur</i>
S—R	1.8% xx	1.4% xx	0.5% x
S—G	5.4% xxxxxx	4.2% xxxxx	5.1% xxxxxx
S—M	1.3% x	1.4% xx	1.1% x
S—P	0.3%	1.4% xx	0.3%
G—M	8.4% xxxxxxxx	9.9% xxxxxxxxxx	9.8% xxxxxxxxxx
G—P	1.0% x	0.9% x	1.1% x
M—P	5.5% xxxxxx	5.2% xxxxxx	10.0% xxxxxxxxxx
M—D	0.8% x	0.9% x	0.8% x
M—N			0.3%
P—D	0.8% x		0.8% x
P—N	7.0% xxxxxxxx	2.8% xxx	3.0% xxx
P—S			1.3% x
N—S	8.6% xxxxxxxx	9.0% xxxxxxxxxx	8.3% xxxxxxxx
N—R		0.5% x	
10.2.1		10.2.2	10.2.3

TABLE 10.2 TWO-NOTE AVAROHA-SANGATI-S: BIHAG

<i>Vedi</i>		<i>Patwardhan</i>	<i>Thakur</i>
R—N	2.0% xx	5.7% xxxxxx	3.7% xxxx
S—N	3.7% xxxx	1.9% xx	3.5% xxxx
N—D	2.9% xxx	2.4% xxx	2.4% xxx
N—P	0.2%		0.8% x
N—G	0.2%		0.3%
D—P	3.9% xxxx	0.5% x	0.3%
D—M	0.7% x	2.4% xxx	4.1% xxxx
D—G	0.5% x	0.5% x	0.2%
P—M	3.9% xxxx	6.1% xxxxxx	6.8% xxxxxxx
P—G			0.5% x
M—G	7.9% xxxxxxxx	13.7% xxxxxxxxxxxxxx	11.4% xxxxxxxxxx
M—S	0.2%		0.2%
G—R	3.4% xxxx	3.3% xxxx	2.7% xxx
G—S	0.2% xx	0.5% x	1.7% xx
G—N		0.5% x	0.6% x
R—S	3.2% xxx	1.4% xx	0.3%
10.2.4		10.2.5	10.2.6

TABLE 10.3: TWO-NOTE AROHA-SANGATI-S: KALYAN

<i>Vedi</i>	<i>Patwardhan</i>	<i>Thakur</i>
S—R 0.2%	1.9% xxx	0.5% x
S—G 0.2%	—	0.1%
S—P —	—	0.1%
R—G 6.1% xxxxxxxxxxxx	3.9% xxxxxx	8.5% xxxxxxxxxxxxxxxx
R—M 1.4% xx	2.6% xxxxx	1.1% xx
R—P —	—	0.2%
G—M 4.9% xxxxxxxxx	2.6% xxxxx	4.3% xxxxxxxxx
G—P 0.5% x	1.0% xx	0.7% x
G—D 0.3% x	—	0.4% x
M—P 2.1% xxxx	2.3% xxxx	3.5% xxxxxx
M—D 5.1% xxxxxxxxxxxx	3.2% xxxxxx	4.5% xxxxxxxx
M—N 0.5% x	1.0% xx	1.4% xx
P—S 0.2%	—	—
P—D 0.6% x	0.6% x	0.2%
D—S 1.0% xx	2.3% xxxx	1.5% xxx
D—R —	—	0.2%
D—N 7.0% xxxxxxxxxxxxxx	3.2% xxxxxx	5.3% xxxxxxxxx
N—S 2.1% xxxx	3.2% xxxxxx	1.2% xx
N—R 7.3% xxxxxxxxxxxxxxxx	5.5% xxxxxxxxxxxx	6.5% xxxxxxxxxxxx
N—G 1.6% xxx	1.3% xx	2.3% xxxx
10.3.1	10.3.2	10.3.3

TABLE 10.3: TWO-NOTE AVAROHA-SANGATI-S: KALYAN

<i>Vedi</i>	<i>Patwardhan</i>	<i>Thakur</i>
S—D 0.6% x	—	0.1%
S—N 3.5% xxxxxx	1.9% xxx	2.9% xxxxx
R—S 3.0% xxxxx	0.6% x	2.4% xxxx
R—D 1.6% xxx	2.3% xxxx	0.4% x
R—N 1.3% xx	5.5% xxxxxxxxxxxx	3.5% xxxxxx
G—R 3.5% xxxxxx	5.8% xxxxxxxxxxxx	6.9% xxxxxxxxxxxx
G—N 1.4% xx	—	0.7% x
M—R 0.8% x	0.6% x	1.4% xx
M—G 5.1% xxxxxxxxxxxx	4.9% xxxxxxxxxxxx	3.2% xxxxxx
P—R —	1.6% xxx	1.3% xx
P—G —	—	0.4% x
P—M 3.3% xxxxxx	3.2% xxxxxx	2.9% xxxxx
D—G 0.2%	0.3% x	—
D—M 1.1% xx	1.9% xxx	2.9% xxxxx
D—P 3.5% xxxxxx	2.6% xxxx	1.0% xx
N—M 0.3% x	—	1.3% xx
N—P —	—	0.1%
N—D 3.0% xxxxx	2.6% xxxx	4.9% xxxxxxxx
10.3.4	10.3.5	10.3.6

11. Comparison: Raga Bihag

11.1 Stylistic Differences

The above tables make several things clear. Notice that all three musicians have more *sangati-s* with higher percentages in *aroha* (ascending movement) than they do in *avaroha* (descending). This means that they have expressed the raga through a greater proportion of ascending then descending phrases. The main path of the raga's ascent, Ni-Sa-Ga-Ma-Pa-Ni² is clearly indicated by the strong lines. There is close agreement on the general weight of the strong lines with two exceptions:

1. Thakur has made nearly double the use of M-P than the other two. The exceptionally heavy lines G-M and M-G mean that a lot of repetition is occurring here. Why Thakur has made twice the use of M-P than the rest becomes clear when we look at his *nyasa* (5.1). There he has a 7 percentage point split between *gandhara* (E) and *pancama* (G) while Vedi has a 19 percentage point split and Patwardhan has 52% difference between the two. Thakur's higher use of *pancama* (G) as *nyasa* than Vedi's or Patwardhan's means that he is ending more phrases in this region of the fourth on *pancama* (G) while the rest end them on *gandhara* (E).

2. Vedi has taken more than twice the P-N as the others. Why that should be so can be seen by looking at his use of *nishada* (B) as *nyasa* and *amsha*. He has used a third more *nishada* (B) as *amsha* and over twice as much as Thakur or six times as much as Patwardhan for *nyasa*.

Look at the minor *sangati-s* and you will start to see more stylistic variations. All three take the large step S-M but Thakur has used two other larger steps (M-N, P-S) that the others have not touched. Similarly, Patwardhan has shown the use of another: S-P. Large steps have the effect of boldness. This feature of the raga shows also in *avaroha* where all three have made use of D-G, Vedi and Thakur have shown N-G and M-S, and Patwardhan and Thakur shown use of G-N. On the whole, Thakur's approach shows the most boldness.

11.2 Approaches to Nyasa-s

How does one approach the two clear *nyasa* notes, *sadja* (C) and

2. Since *gandhara* (E) is *amsha*, the tetrachords should be divided from *nishada* (B) as we saw in 1.1

gandhara (E) in this raga? Looking for Sa in the second position of a *sangati* pair gives us the following possibilities:

TABLE 11.2.1: APPROACHES TO SADJA (C)

<i>Sangati</i>	V—P—T—	Total %	Remarks
1 N—S!	+ + +	25.9/3	probable <i>aroha</i> approach
2 P—S	+ + +	1.3/3	unlikely final approach
3 R—S!	+ + +	4.9/3	probable <i>avaroha</i> approach
4 M—S	+ + +	0.4/3	unlikely final approach

There are two likely ways to approach *sadja* (C): either from directly below, or from directly above. Let us examine both approaches to see from which note each itself is coming.

TABLE 11.2.2: APPROACHES TO SADJA (C) VIA RISHABHA (D)

<i>Sangati</i>	V—P—T—	Total %	Remarks
1 S—R	+ + +	3.7/3	simple turn
2 N—R	+ + +	0.5/3	seldom used
3 G—R	+ + +	9.4/3	probable approach

TABLE 11.2.3: APPROACHES TO SADJA (C) VIA NISHADA (B)

1 M—N				0.3/3	seldom used
2 P—N	+	+	+	12.8/3	probable <i>aroha</i> approach
3 G—N		+	+	1.1/3	unlikely approach
4 R—N	—	—	—	11.4/3	probable <i>avaroha</i> approach
5 S—N	—	—	—	9.1/3	simple turn

Therefore the approaches to *sadja* (C) are:

1. P-N-S
2. R-N-S
3. G-R-S

The data shows that VEDI prefers a straight descent (G-R-S), while Patwardhan and Thakur prefer to descend by way of *nishada* (B) (G-R-N-S). This is evident from the relatively little use he gives to R-N.

11.3 How does one Approach Gandhara (E)?

Study the above tables for Bihag and you will see that the main approaches to *gandhara* (E) are from *sadja* (C) below and from *madhyama* (the fourth) above. Does one ever approach *gandhara* (E) by S-G and stop just there? In other words, is *gandhara* (E) a *nyasa* when it arrives by way of S-G? Furthermore, since P-M is a strong line does that mean that one arrives at *gandhara* (E) with the phrase P-M-G and just stops, just like that? Or does one descend to *gandhara* (E) with a turn such as P-M-G-M-G? The strong lines G-M and M-G do indicate a lot of activity in that region, but there is no way we can be sure from the information given above that Bihag's special turn is called for.

The simple fact is that we cannot know the *sangati-s* that conclude phrases or evaluate the importance of turns (such as Bihag's all important G-M-G) without looking at at least three elements in a series, two notes and the end of phrase-marker, or three notes. Let us continue this discussion after looking at Kalyan.

12. Comparison: Raga Kalyan

12.1 Aroha and avaroha Structure

In the tables (8.3) it is quite evident figures that the basic structure of Kalyan in *aroha* is (N-R-G-M-D-N) while its *avaroha* is (R-S-N-D-P-M-G-R). Furthermore, one can see that in the two *anga-s* (tetrachords) there are the *aroha-s* (R-G-M-P) and (M-D-N-S). Proof of this lies in the strong lines up to the upper note of the tetrachord and the fact that there are no further strong ascending lines from these notes (S,P).

12.2 Stylistic Differences

Compare the figures for R-S and R-N and notice that Patwardhan prefers to come in decent to *sadja* (C) by way of *nishada* (B) which is opposite what Vedi prefers. Patwardhan has also used R-M more than Vedi or Thakur, but both Vedi and Patwardhan prefer much more R-D than does Thakur. Especially Vedi likes to approach *pancama* (G) directly from *dhaivata* (A) rather than by way of *madhyama* (the fourth) as especially Thakur does (see the figures for D-P and D-M). Thakur, again, has shown the preference for the bold long leaps. These major stylistic differences are clear in the data analysis.

13. Lines and turns: the Three note Combinations (varna-s)

13.1 Ideas of the Sanskrit Musicological Tradition

As we mentioned, in order to discover which melodic turns are important in a raga, we require our smallest data unit to contain three items in a series. For this we are justified to use Sarangadeva's idea of the *varna-s* (S.R.6.1-3b). The term '*varna*' refers to categories of melodic movement. There are four:

1. *sthayi-varna* = repeating a note,
2. *arohi-varna* = ascending from one note to another,
3. *avarohi-varna* = descending from one note to another,
4. *mishrita varna* = mixed categories of the above three.

In a way we have already covered the first three of these four in the previous section dealing with two-note *sangati-s*. But the term *varna* includes the fourth or mixed categories (the turns) for which three notes in a series is required. Since the turns (*mishrita varna-s*) are proper members of the set of *varna-s* we require to take up the subject again in the context of more than two notes in a series. For convenience, I restrict the term '*varna*' here to refer to three-note groups, which I sometimes also call 'kernels' (see below). I use the term '*sangati*' then to refer to a two-note connection.

14. Context Analysis: Using the varna-s as 'Seeds' or 'Phrase Kernels'

14.1 Analysis and Format Features: the Context Index

Once the computer has processed the data, it knows which three-note combinations (*varna-s*) have occurred, and in what percentages. The computer lists them in rank order and creates an index to the list showing the context in which each *varna* or Kernel-combination has occurred in the data. What the computer does is to look forward and backward from each Kernel to find the (up to) two notes which have preceeded or followed it. A series of special markers is used to express the results of the search. If it finds two notes in the context on either side of a given kernel, and sees that there are more notes too, then it prints an ampersand (&). The phrase itself is printed in square brackets. Thus an entry of the form "&ab [cde] fg&" means there were more than two notes preceeding the phrase kernel 'cde'; 'a' was the first, 'b' was the second. It was followed by more than two notes, 'f' being the first and 'g' the second.

If there were only two notes found in the context search, the computer prints an exclamation point (!) instead of an ampersand. If there was only one note found, it prints an apostrophe (') before or after the note found, depending on its position before or after the kernel. If the computer finds no notes preceeding a kernel, ie., if it finds that the kernel has begun a phrase, it prints the symbol '>' before the left bracket. If the kernel itself has ended a phrase, the symbol printed after the right bracket is (;).

14.2 Context Trees

The index brings together a lot of information in a short form, revealing exactly the context of each kernel's use and how it may have changed over time. From the context index we can create 'possibility-trees' to summarize what happens just before and just after a given kernel. Note too that since the phrase and subphrase delimiters may be one of the elements in the kernel we can know how phrases start, and how they end. In addition, we can know which note starts the next phrases following the note which ended the previous one (when the phrase delimiter is the middle element of the kernel). Here we can get an answer to what happens in Bihag's approach to *gandhara* (E).

14.3 Answers to Earlier Questions Using the Context Trees

Confining our discussion just to the material of D.C. VEDI, let us study the region of Bihag around *gandhara* (E). To end a phrase with M-G is so common, the kernel [MG;], where, ';' is the end of phrase delimiter, appears in ninth position in the list of 98 entries of the three-note patterns. Studying the context closely reveals that mostly it was approached (& M-G-M-G;), i.e. with the well known turn characteristic of Bihag. It was also approached in a variety of other ways, (>S-G-M-G;), (& D-G-M-G;), (& M-P-M-G;) and (>N-S-M-G;), but they happen less frequently.

We can also look at the fate of P-N-S in the light of context analysis. The kernel is third on the list of 98. Here is its context tree.

TABLE 14.3.1: KERNEL [P-N-S] CONTEXT TREE

$\begin{array}{c} >+++++ \\ > \dots M \dots \\ > \text{---} G \text{---} M \text{---} \\ \& \text{---} G \text{---} M \text{---} \end{array}$	[P-N-S]	$\begin{array}{c} \text{---}; \\ \text{---} G \text{---}; \\ \text{---} G \text{---} R \text{---} \& \\ \text{---} G \text{---} M \text{---} \& \\ G \dots S \dots \& \\ \dots R \dots S \dots \& \\ \text{---} R \text{---} N \text{---} \& \\ \dots P \dots N \dots \& \\ \dots M \dots G \dots \& \end{array}$
$\& \dots N \dots S \dots$		
$\& \dots S \dots N \dots$		

Order of importance: | + | = | - | . | .

A lot is revealed in the context tree. This particular kernel [P-N-S] is entered mainly in three ways. Most often it is the start of a phrase itself. If it comes in the middle of some phrase, most likely it will be approached by G-M. It may, however, be started from G-M. On rare occasions it has been entered from above with N-S or S-N. After the kernel [P-N-S], if the next note is *gandhara* (E), which is a strong probability, the melody will, in the order likely, descend to *rishabha* (D) and continue, ascend to *madhyama* (the fourth) and continue, or the phrase will end there. There is an equally strong probability that the first note after the kernel will be *rishabha* (D). When this is the case, the melody will mostly continue to *nishada* (B), but it goes to *sadja* (C) from time to time. Likewise occasionally one finds it falling back to *pancama* (G), and rising as high as *madhyama* (fourth) before falling back to *gandhara* (E).

15 Steps Towards a Generative grammar and Synthesis

15.1 Generating Phrases

Since the (up to) two notes preceeding and following any given kernel can be isolated, they may be matched up by overlapping the output notes from one kernel with the input requirements for another. In this way, they can be linked together for generating phrases.

The distinctive feature of a phrase, of course, is that it has a distinct beginning and end. There must be a way, therefore, to 'open' a phrase and to 'close' it, and to then open another, etc. From context analysis we can understand how to: (1) start phrases, (2) add to the middle of phrases, (3) end phrases, and (4) begin new phrases. Notice that we ignore the question of rhythm in dealing with the *sangati*-s: that is a different study.

There is a suspicious element in all of this, even in the very idea of the tree of input/output possibilities itself, as presented. It is that you cannot be sure by looking at the context tree which input *sangati*-s are followed by which output *sangati*-s after a given kernel. All of the in and out *sangati*-s were, indeed, used but we do not know which went with which. The same is true with the process of 'overlapping'. We can overlap, but we do not know whether we have a combination that actually occurred.

This consideration brings us to ask the question, "Do we want to generate phrase combinations other than those found in the analysis? If so, then we will be content with the freedom to recombine possibilities in new ways.

15.2 *Influence of Context on the General Statistical Background of Tendencies to Go from Note (n) to Note (m)*

It is interesting to observe how a given context can affect the overall statistical background of possibilities of taking one particular note after another. By the term 'general statistical background' I mean the overall chance of any one note following any other, as these probabilities are summarized in the *Sangati* lists (9.2). We can find many instances where a particular context rules out certain steps which otherwise would have a high probability of occurring. The opposite case also happens, where low-probability *sangati*-s become highly probable in certain contexts.

To understand this better, suppose we focus attention on the two note outputs from a phrase which has several. Take the case of [N-R-G] of VEDI's Kalyan. Its actual possibility-tree (at output) is:

TABLE 15.2.1: KERNEL [N-R-G] CONTEXT TREE: VARNA-S (3-NOTE)
PROBABILITIES FOUND

Input	Kernel	Attractive intensity	First note	Attractive intensity	Second note
> —	[N-R-G]—>	+25%	N	12%	G
		6%	D	88%	R+
				100%	N
		+53%	M	53%	D+
				35%	P=
				12%	R
		3%	G	100%	M
		12%	R	100%	M

Not all combinations of passing from any first (output) note to a second are used, nor are those used all equal in their probability of occurring. What actually occurred, and how often, is indicated by the percentage figures which mark the tendency for it to go one way or the other. Compare this with the predictions of the general background in the table below.

15.3 A Hypothetical Context Tree for [N-R-G] Based on the Relative Weights of the Two-note Sangati-s

TABLE 15.3.1: GENERAL STATISTICAL BACKGROUND

		input	probability to pass to 2nd note					
		[N-R-G] ↓	R	G	M	P	D	N
probability	[34%]	R—	0	[59%]	[14%]	0	[15%]	[12%]
to take	2%	G—	[32%]	2%	[45%]	5%	3%	[13%]
first	[48%]	M—	8%	5%	6%	[22%]	[53%]	5%
following	3%	D—	—	2%	9%	[30%]	—	[59%]
note:	[14%]	N—	[58%]	[13%]	2%	—	[24%]	2%

15.4 Comparison of Context and Background

If we take only the two most prominent possibilities out of each row in the above table, we can make a tree not so much unlike the one above (15.2.1). It is interesting to compare the differences of

the two. I have, therefore, added two columns 'Extra' and 'Dropped' to the tree below. The first, 'Extra', means that the *sangati* is predicted by the general statistical background, but it is not found in the original context analysis (hence it is extra). The second column, 'Dropped', means that the *sangati* of the original analysis named in the column has not appeared in the general background prediction (hence 'Dropped'.)

TABLE 15.4.1: KERNEL [N-R-G] CONTEXT TREE (SANGATI TWO-NOTE PROBABILITIES)

	Attr.	Note	Attr.	Note	Extra	Dropped
>-[N-R-G]->	3%	D	59% 30%	N+ P	(DP)	
	+48%	M	22% 53%	P D+		(MR)
	14%	N	24% 58%	D R+	(ND)	(NG)
	+34%	R	15% 59%	D G+	(RD) (RD)	(RM)
	2%	G	32% 45%	R M+	(GR)	

15.5 Effect of the Context

Looking at the details it is not difficult to understand why "DP", the first entry in the 'Extra' list, would not occur in the context of [N-R-G]. This particular *sangati* would not be suitable to follow the ascending kernel [N-R-G] because it would only make musical sense if it were executed from the register above the kernel, not below it. The ascending *sangati* G-D connecting the kernel [N-R-G] with the *sangati* D-P would be unusual in Kalyan. Looking at the actual context which happened we can see that the ascending phrase [N-R-G] when followed by *dhaivata* (A) actually descends to reach *dhaivata* (A) and then continues to ascend. It means G-D is a descending *sangati*. Similarly the second 'Extra' N-D which shows up in the general prediction, but is not taken in this context, would not occur after [N-R-G] for the same reason.

Another way to sum up the reason is to say that it would be musically weak to follow an ascending stepwise phrase with a

descending stepwise phrase after making a large descending jump. In both of these cases an ascending phrase is followed by a note either equal to or lower in pitch than the first note of the phrase (in this case *nishada* (B)). Study of the context shows that in both these cases it still is an ascending movement which is occurring, but that it has been broken off and restarted from a lower position.

This could probably be generalized into an aesthetic rule and be applied to descending phrases too. If so, the rule would state something like this: "If the first note following an ascending/descending pattern is a fourth or more away from the last note of the phrase, probably it will continue in ascent/descent but restarting lower/higher than the original pattern."

Look at the remaining three 'extra' possibilities which are found in the general statistical prediction, namely R-D, R-G, and G-R. In fact, all of them are quite good and should not be ruled out. Perhaps they would not be, if our analysis were coming from a larger data base. But if we allow these other possibilities, we shall require a well defined set of rules to exclude melodic 'non sequiturs', such as the one above, which may arise. Look at the *sangati*-s which have been 'dropped' in the general prediction. Evidently, circling around *gandhara* (E) as they do, their importance is precisely in this kind of context, i.e. [N-R-G].

16. Summary

We began with looking at concepts available in *Sangita-shastra* to differentiate the type of use notes get in ragas. Applying these concepts to the analysis of two ragas, Bihag and Kalyan, we discovered that each raga and, indeed, each rendition used as data showed its own patterns of note use. In order to investigate what happens to the serial order of notes in a raga, we looked at two-note and finally three-note "seed-paths" of melodic movement. This led us to looking into the question of seeing the context of use for the three-note "seeds". We ended our discussion looking at how a generalized prediction of melodic movement possibilities in a raga based on a stochastic analysis differs from a prediction made by context analysis. □

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